

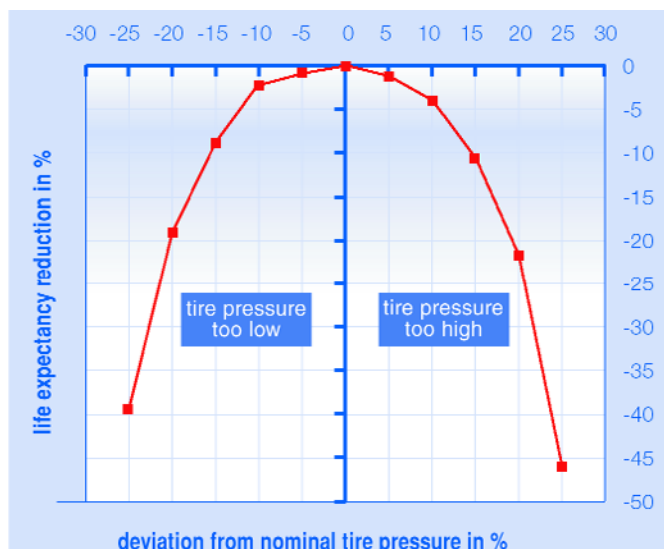


Figure 1. Relation between tyre pressure and wearing. (Wabco)

Wireless Tyre Pressure Monitoring

Helmuth Lemme

Sudden tyre failure is not only annoying but also downright dangerous. In the future, new technology will help to reduce the number of accidents caused by tyre problems, with recently developed sensor systems constantly guarding tyre pressure and issuing a warning signal well before disaster strikes.

In 85% of all cases, tyre rupture or explosion is caused by too low pressure. The real cause, however, is increased friction leading to excessive tyre temperatures and material failure with often catastrophic consequences. Slightly less worrying, even a small loss of tyre pressure causes not only increased wear but also higher fuel con-

sumption due to increased rolling resistance. Just as with too high pressure, the life expectancy of the tyre is significantly reduced (**Figure 1**). Since there are no tyres with zero rolling resistance, and pressure checks by the vehicle driver are insufficient, an electronic alternative appears useful and more than welcome. The first systems are now in

volume production. Each wheel contains a module measuring the tyre pressure and temperature at regular intervals and copying the resulting data to the vehicle computer. The computer responds to too low or too high values by lighting a warning indicator on the dashboard. In the USA, the National Traffic Safety Admin-

istration has made the use of a TPMS (tyre pressure monitoring system) compulsory for new cars as of November 2003. It is expected that Europe and Japan will follow suit in the not too distant future.

From a point of view of technology used, individual manufacturers seem to follow their own ideas. The oldest princi-



Figure 2. Parts constituting Beru's TSS (tyre safety system)



Figure 3. No more batteries in the future: passive-sensor interrogation using RFID techniques (Siemens/Goodyear).

ple works indirectly: a micro-computer compares the rotational speed of all wheels, using data supplied by ABS (anti-blocking system) sensors. This principle is used by, among others, Continental for their DDS (deflation detection system). If the tyre pressure on one wheel drops, the effective wheel radius becomes smaller causing a higher rotational speed. Although such systems are cost-effective, they suffer from a high detection threshold (approx 30% pressure loss). Also, gradual pressure loss on all tyres goes by unnoticed. Systems with real sensors inside the tyres are far more secure. The technical challenge boils down to the ability to convey measured values from the rotating wheel to the vehicle chassis. Slip rings are too unreliable because they soil easily. Today, the standard principle is a radio link. The measurement module on the wheel not only contains a microcontroller that turns the values supplied by the pressure and temperature sensor into a digital data packet, but

also a small RF transmitter operating in one of the ISM bands (usually 433 MHz, rarely on 2.4 GHz). The unit is powered by a Lithium battery which should last for a couple of years but is nonetheless a serviceable part. The module should be up to harsh conditions: strong vibrations with dynamic peak acceleration exceeding 2000 g, dirt, water, salt, ice and snow, yet have the smallest possible dimensions and weight. A receiver antenna is fitted in each wheelcase, or a single antenna centrally located under the chassis. A second microcontroller computes the measured values.

The above systems are available from Beru (TSS, tyre safety system, **Figure 2**), Wabco/Michelin (IVTM, integrated vehicle tyre pressure monitoring), Continental (TPMS, tyre pressure monitoring system) and a few other manufacturers. In principle they are similar, but different when examined in detail. For example, the Beru wheel mod-

ule that forms a compact unit with the tyre valve is fitted inside the tyre on the wheel rim — meaning it can only be built into a vehicle by the factory. The Wabco/Michelin module is fitted outside the wheel rim, secured to the valve with small pneumatic tubes so it can be 'retro-fitted' without so much as having to remove the tyre. Other systems for trucks and utility vehicles differ widely because of the large variations in tyre pressure.

Batteryless systems

The Lithium battery is a source of problems with all systems. Exchanging the battery is time-consuming. The battery is also heavier than the entire electronic circuit and it obviously requires a very stable mounting method in view of the centrifugal acceleration. When braking hard, the temperature inside the tyre can reach up to 100 degrees C which may easily damage the bat-

tery. Finally, flat Lithium batteries are toxic waste hence have to be disposed of using the proper channels.

A solution to the above problems was found in the use of passive sensor responders that are interrogated over radio. The RF energy allows the transponder to return the instantaneous tyre pressure 'over the air'. The sensor goes inactive again until the next RF trigger arrives. The principle is well established in RFID ('radio tagging') systems that have been around for years. The technology offers several options. One very elegant solution is called 'surface-wave elements'. A system using these devices was developed by the Siemens research labs but never made it to volume production. Instead, Siemens in co-operation with Goodyear are now working on a different system which reportedly is cheaper as well as less complex. Here, the transmission is inductive: inductors are fitted on the wheel and the wheel holder, the assembly producing a

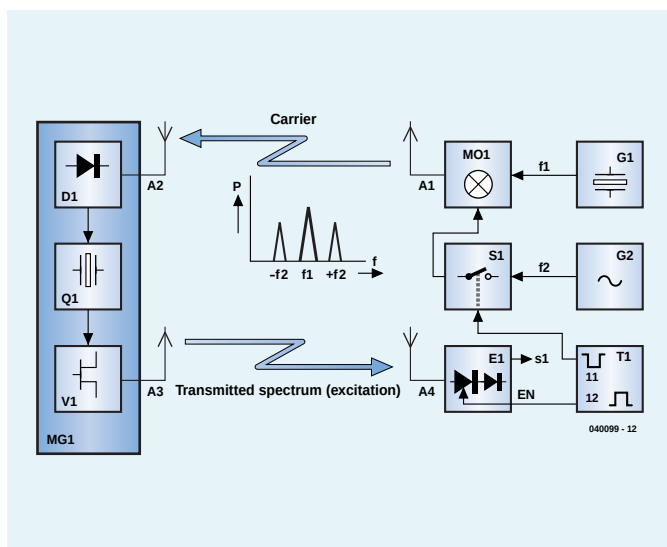


Figure 4. Quartz crystal based sensor: principle of the 'Tyretronic' pressure and temperature sensor system. (Q Mobil)

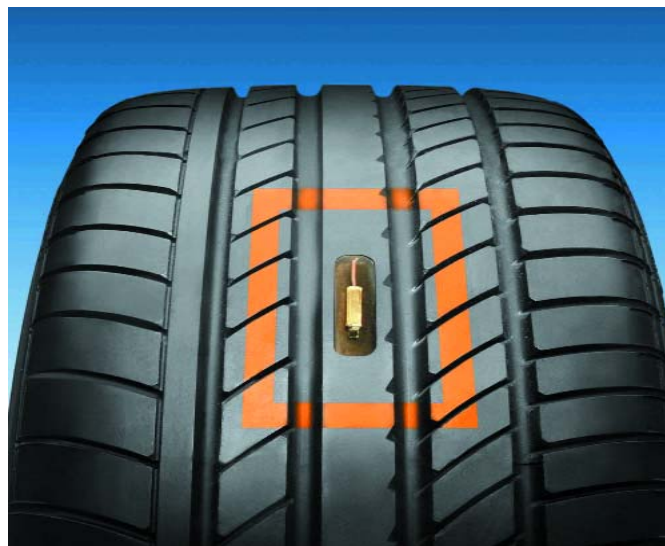


Figure 5. The 'Darmstadt tyre sensor' measures road contact by interpreting tyre profile deformation.

transformer effect (**Figure 3**). A short RF pulse at a carrier frequency of 125 kHz supplies the energy for the measurement and returning of a data packet containing the current tyre pressure. The system is to be perfected for launching in 2006.

Quartz crystal sensors

Still another principle has been adopted by IQ Mobil (Munich, Germany) for their tyre pressure monitoring systems. The central part is a quartz volume oscillator producing a controlled amount of 'ringing'. The interrogator module emits a microwave signal (at 2.45 GHz) which is amplitude-modulated with a frequency between 6 MHz and 10 MHz. Inside the responder, the RF burst is rectified and the resulting voltage used to excite the quartz crystal (within approx. 1 ms). Next, the AM modulation is removed from the carrier. The quartz crystal will continue to oscillate at its own frequency, but

subject to the capacitance presented by the pressure sensor. The result is crystal 'pulling' to a frequency removed from the excitation frequency. The resultant ringing (oscillation decay, lasting about 2 ms) is mixed with the carrier frequency, hence modulated by it and returned as an RF signal. The control module measures the modulation frequency of the responder signal and employs the deviation from the excitation frequency to calculate the pressure value. (**Figure 4**). The entire interrogate-and-respond sequence is completed within 6 ms. The (small) temperature coefficient of the quartz element responsible for the pressure measurement is compensated. In this way, pressure measurements can be performed at an accuracy of ± 0.1 bar (1.45 psi). The second measurement channel is for temperature and employs its own quartz crystal with a different cut angle and a much larger temperature coefficient. In practice, it allows an accuracy of ± 1 K (kelvin) to be achieved. The

return carrier is alternately modulated with the two crystal resonance frequencies. Extensive tests showed that the system is immune to other RF sources in the 2.4-GHz band (say, from other cars). This is achieved by measures including frequency hopping after each sensor interrogation action. The usable range of the RF links is about 1 m. The size of the module is 22×22 mm and its weight, approximately 14 g. The system will be taken into volume production by the Japanese company Alps. Reportedly the unit cost should remain under 1 US\$. The chip could also be programmed to contain data on the tyre used. This may be useful for car production logistics or even to inform the car computer new tyres have been fitted.

Road contact sensors

Still more security is afforded by an additional tyre parameter which is actually the most important: road contact. Using

this real-time information, anti-blocking and vehicle stabilisation systems could be made to work even better. The 'Darmstadt tyre sensor' (**Figure 5**) is a joint development by Continental and the University of Darmstadt (Faculty of Vehicle Technology, Prof. Winner). It records deformation of the tyre profile elements when in contact with the supporting surface. The current version employs a surface-wave sensor in the tyre profile and has not yet left the test bench. The adaptation to 'real life' on the road is problematic because the sensor is expected to measure as well as transmit when it is in contact with the road. At that instant, the RF contact is hindered by the wheel rim. There remains a lot to explore and research. If, however, researchers are successful, they can pride themselves in having reduced the number of road accidents even further.

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